Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington D.C. 20554

In the Matter of	)	
	)	
Unlicensed Operation in the TV Broadcast Bands	)	ET Docket No. 04-186
	)	
	)	
Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band	)	ET Docket No. 02-380
	)	

COMMENTS OF

Shure Incorporated

November 30, 2004

SUMMARY

Shure Incorporated ("Shure") presents these Comments in response to the Commission's Notice of Proposed Rulemaking ("NPRM") in ET Docket Nos. 04-186 and 02-380 which proposes to make additional spectrum available in the television (TV) broadcast bands for unlicensed devices. Shure is a leading, respected manufacturer of professional wireless microphones and other wireless audio products that operate within the 470-806 MHz band under Section 74.861 of the Commission's Rules as Low Power Auxiliary Stations. Shure supports the Commission's efforts to make more spectrum available for unlicensed devices, but is concerned that allowing unlicensed devices in the TV broadcast band, as proposed in the NPRM, would not adequately protect existing important uses of the TV spectrum such as wireless microphones.

Wireless microphones are vital to modern broadcast programming and motion picture production. They are used widely by the news and entertainment media, in schools and houses of worship, and at sporting events and political conventions. In order to deliver the high level of sound quality and reliability that wireless microphone users expect, wireless microphones must operate in a known, stable interference environment.

The Commission made several assumptions in the NPRM to conclude that wireless microphones would likely not experience harmful interference from unlicensed devices in the TV band. Specifically, the Commission determined that interference would be unlikely because (1) wireless microphones are permitted to operate at relatively high power; (2) wireless microphones are used at relatively short working distances; and (3) wireless microphones use FM transmission which exhibits a "capture

effect" that rejects co-channel interference. These assumptions, however, do not hold up to scrutiny. Shure analyzed these assumptions and found that (1) the vast majority of wireless microphones operate at much lower power levels than assumed by the Commission; (2) even at relatively short distances, wireless microphones experience co-channel interference from unlicensed devices; and (3) wireless microphones derive only a moderate amount of benefit from the "capture effect" because they occupy a relatively small bandwidth. Thus, unlicensed devices have the very real potential to adversely affect wireless microphones if implemented as proposed in the NPRM.

Shure also conducted dynamic "real world" tests of wireless microphone operation in the presence of co-channel interference. Shure's test results reinforce the need for unlicensed devices operating in the TV spectrum to implement cognitive radio functions to avoid causing harmful interference to incumbents.

Shure proposes a three-part interference mitigation solution to protect the wide variety of important wireless microphone uses from harmful interference from unlicensed devices. Specifically, to mitigate potential interference the Commission should (1) identify 2 VHF TV channels and 4 UHF TV channels to be exempt from unlicensed device operations; (2) require unlicensed devices to employ spectrum sensing/dynamic frequency selection techniques in a distributed, cognitive fashion; and (3) implement a "smart" beacon system which would operate on one of the vacant TV channels being used by the wireless microphone system and transmit information concerning the TV channels in use by various wireless microphone systems. Shure recommends numerous specific additional technical and operational requirements to increase the effectiveness of these mitigation solutions with fixed/access point-to-

multipoint systems, fixed/access-to-portable systems, and personal/portable peer-to-peer systems. Based on its significant study and informal testing, Shure urges the Commission to adopt its proposed interference mitigation solutions and specific technical and operational requirements as measures complementary to any requirements that may be adopted to address potential interference to TV signals. Finally, it is critical that the Commission codify all of these requirements into the Commission's Rules to ensure that incumbent users are adequately protected from harmful interference from unlicensed devices.

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COMMENTS OF

Shure Incorporated

Shure Incorporated ("Shure") is pleased to submit these Comments in response to the Notice of Proposed Rulemaking ("NPRM") in the above-captioned matter.[1] Shure supports the Commission's efforts to make additional spectrum available for unlicensed devices in the vacant television (TV) broadcast bands as long as this can be done without causing interference to existing licensed users. Due to the fact that these unlicensed devices are expected to be deployed in very large numbers (perhaps in the millions) with little or no control over how or where they would be used, interference issues must be considered with due diligence. Shure is concerned that the new rules, as proposed in this NPRM, will not adequately protect existing important uses of the TV spectrum, notably wireless microphones and other wireless audio systems. These devices, known collectively as Low Power Auxiliary Stations ("LPAS"), operate as licensed secondary users under Part 74 of the Commission's Rules.

[1] *Unlicensed Operation in the TV Broadcast Bands*, ET Docket Nos. 04-186, 02-380, Notice of Proposed Rulemaking (released May 25, 2004).

Because of these concerns, Shure has been actively working with the FCC and other interested parties, including the IEEE 802.18 Radio Regulatory Technical Advisory Group (RR-TAG), IEEE 802.22 Wireless Regional Area Networking Working Group, the Consumer Electronics Association, and individual members of these groups to identify technical and operational solutions that will permit unlicensed devices to operate in the vacant television broadcasting spectrum without causing harmful interference to wireless microphones. No prototypes have been built or tested in "real world" situations to show how well interference mitigation techniques, such as dynamic spectrum sensing discussed in the NPRM, would work to protect television reception, or wireless microphones, or wireless audio systems within the TV bands. As discussed further herein, Shure has experimentally verified the nature and extent of interference to wireless microphones that **would occur** if the proposed mitigation techniques were ineffective or were not applied. Based on Shure's technical analysis and experiments, Shure herein proposes a three-part interference mitigation solution that it believes would, if adopted as proposed herein, allow unlicensed devices to operate in the TV spectrum without disrupting existing wireless microphone operations. **To the extent that effective technical and operational safeguards can be developed, these requirements must be codified in any new rules allowing unlicensed devices to operate in the TV bands**.

Statement of Interest

For nearly eighty years, Shure has been a respected U.S. manufacturer of high quality, innovative audio products. Today, headquartered in Niles, Illinois, Shure is a global leader in audio electronics, including professional wireless audio products that

operate within the 470-806 MHz band under Section 74.861 of the Commission's rules, 47 C.F.R. § 74.861, as Low Power Auxiliary Stations ("LPAS"). As such, Shure is well-qualified to comment on the issues raised in this proceeding. Shure holds grants of Equipment Authorization (Certifications) from the Commission for these products. Shure has also participated in previous Commission proceedings involving LPAS devices (including comments and reply comments to the Notice of Inquiry in this proceeding).[2]

Background

On December 11, 2002, the Commission adopted a Notice of Inquiry ("NOI") in this proceeding seeking comment on the possibility of allowing unlicensed devices to operate in the TV broadcast bands at locations and times when the spectrum is not being used by authorized services.[3] The Commission observed that unused portions of the TV spectrum appear to be a suitable choice for expanded unlicensed operations because there is significant bandwidth available since each TV channel occupies only six megahertz and multiple channels are typically vacant or unused in a particular area. The Commission stated that allowing unlicensed devices to operate on unused TV channels would not only lead to more efficient use of the spectrum, but also benefit consumers by making more spectrum available for unlicensed wireless broadband

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[2] *See, e.g.*, Comments of Shure Brothers Incorporated, filed September 11, 1997 in **ET Docket No. 97-157**; Reply Comments of Shure Incorporated, filed May 16, 2003 in **ET Docket No. 02-380;** Comments of Shure Incorporated, filed April 17, 2003 in **ET Docket No. 02-380;** Reply Comments of Shure Incorporated, filed August 7, 2001 in **ET Docket No. 01-75; and** Comments of Shure Brothers Incorporated, filed July 16, 1999 in **WT Docket No. 99-168**

[3] *See* Notice of Inquiry in ET Docket No. 02-380, 17 FCC Rcd 25632 (2002). The Commission also sought comment on the possibility of allowing unlicensed devices to operate in the 3650-3700 MHz band with only the minimum restrictions necessary to prevent interference to authorized users of the band. However, the matter of unlicensed operation in the 3650-3700 MHz band is now being addressed in a separate proceeding. *See* Notice of Proposed Rule Making in ET Docket No. 04-151, FCC 04-100 (rel. April 23, 2004).

applications and services. However, numerous commenting parties, including Shure, expressed concern about potential interference from such new unlicensed operations.

On May 25, 2004, the Commission released the instant NPRM. The NPRM states that the Commission "believe[s] that unlicensed devices can successfully operate in the unused portions of the TV broadcast bands without causing harmful interference to television and other authorized services, provided appropriate technologies are used to ensure that such unlicensed devices operate only in vacant spectrum."[4] The NPRM seeks comment on various technical criteria to mitigate potential interference and ensure that unlicensed devices would operate only in vacant spectrum. The NPRM also specifically addresses the issue of wireless microphones, which is Shure's primary concern, finding "that unlicensed use should generally be compatible with wireless microphones."[5] Shure disagrees with this conclusion, and believes that allowing unlicensed devices to operate as proposed in the NPRM would indeed cause harmful interference to wireless microphones. Shure presents its technical analysis and its three-part interference mitigation solution to protect wireless microphones below.

DISCUSSION

I. Wireless Microphones Enable Modern Communications

A. Wireless microphones serve an important public interest in the United States

Today, wireless microphones are vital to the production of almost every type of public event imaginable. Modern broadcast programming and movie making would be

[4] NPRM, ¶ 7.
[5] NPRM, ¶ 38.

almost impossible to produce without them. Radio and Television Electronic News Gathering ("ENG") teams use wireless microphones daily to communicate local and national public safety information to the American public. Wireless microphones enable the American news and entertainment media to maintain a level of excellence in technical operations and content unmatched by the media industry in any other country. In addition, wireless microphones are widely used in schools, houses of worship, governmental affairs, political conventions, law enforcement, sporting events, theatrical performances, and theme parks. Large events like the national political conventions or the Super Bowl have 200 or more wireless systems in simultaneous operation. These large productions already require more "open" RF television spectrum than is currently available -- without the added burden of unlicensed devices.[6]

B. American professionals and consumers use wireless microphones in four different settings

Wireless microphone users fall into four main categories: large and small installations involved in either fixed or itinerant (portable) operation (*see* Table 1 below).

Large Fixed – 20 to 200 channels Network Television Studios, Theme Parks	**Large Itinerant** – 20 to 200 channels Political Conventions, Sporting Events
Small Fixed – 20 or fewer channels University, House of Worship, Movie Making Location	**Small Itinerant** – 20 or fewer channels Electronic News Gathering Teams, Press Conferences

Table 1. Wireless Microphone User Classification

[6] For this reason, productions such as the recent Republican National Convention typically require special temporary authority and/or waivers from the FCC. *See Public Notice*, DA 04-1494, "Grant of Waiver of Separation Requirements of 47 C.F.R. § 74.802 and Special Temporary Authorizations," (released May 26, 2004).

A theme park complex is an example of a large fixed installation that may have several hundred or more wireless microphones and other wireless audio systems in simultaneous operation. For example, the Walt Disney World Company has licenses for 1800 units of wireless microphones (Broadcast Auxiliary Low Power) combined between the company's Florida and California locations. Special events such as the Democratic and Republican National Conventions are examples of large itinerant operations involving similarly large numbers of wireless audio systems. By contrast, a small fixed installation typically requires 20 or fewer wireless microphones and other wireless audio systems, as exemplified by a small house of worship that broadcasts its services over a local TV station. A television ENG crew is an example of a small itinerant operation that typically uses a similar number of wireless audio channels.

C. Wireless microphone users require extremely high audio quality

As the "front end" of the audio chain, the sound quality that wireless microphones deliver must be clear and free of noise and interference. Users expect a wireless microphone to equal the performance of a comparable wired microphone model in every respect. This includes sound quality, ease of use, ruggedness, and reliability. Audio anomalies such as "clicks" and "pops" are not tolerated in this context. In particular, "dropouts" (a momentary loss of sound) caused by interference are completely unacceptable. For example, dead silence in the middle of a newscast will not be tolerated by wireless microphone users -- or their listening audience. Customers who experience any of these problems will assume the product is defective and will return it to the manufacturer for repair. This exceedingly high user expectation is in stark contrast to far lower user expectations for wireless phones, where transmission artifacts

are generally tolerated as long as a call is not dropped entirely.

To meet the very high standards of the American listening and viewing public when it comes to audio quality, broadcast engineers are probably the most critical of all professional users. Broadcast engineers cannot tolerate anything that falls short of meeting the most exacting standard for sound transmission quality. A typical requirement for television broadcast audio quality is over 100 dB of signal-to-noise ratio throughout the duration of the program.

For a live broadcast awards show such as the Academy Awards, the audio engineers, sound crew and producers will typically spend one week installing, configuring, rehearsing and testing the audio systems. These preparations include the frequency coordination and sound check of dozens of wireless microphones, intercoms, and ear-monitors. Due to the extremely complex nature of coordinating frequencies for a broadcast television production, network broadcasters and sound companies engage a professional frequency coordinator to be onsite specifically for these events to ensure that proper planning and implementation occur for a successful interference-free production.

Most consumers are unaware that the sound they hear on a typical network radio or television program probably traveled through a million dollars worth of audio equipment. This reflects why the expectations placed on wireless microphones are so high.

D. Technical characteristics of wireless microphones

Wireless microphones are part of a larger category of wireless audio products that also includes In-Ear Monitor Systems, wireless intercoms, and wireless cueing

(IFB) systems. These systems operate as licensed secondary users on locally unoccupied television channels under Part 74 of the Commission's Rules. Most wireless microphones operate in either the VHF High Band or the UHF band, using FM transmission with an occupied bandwidth limit of 200 kHz. Although Commission Rules allow wireless microphones to use up to 250 mW of power, most models operate with a conducted output power of only 10-50 mW. However, the effective radiated power (ERP) is even lower than the conducted levels due to body absorption and shadowing. This lower power design allows for simultaneous operation of more wireless systems within a given amount of spectrum, conserves battery life, and reduces equipment cost.

E. Wireless microphones require a known, stable interference environment

In order to deliver the high level of sound quality and reliability that users expect, wireless microphones must operate in a known, stable interference environment. The TV bands have proven to be ideal for this application, given that TV stations transmit on known channels that seldom change. Wireless microphones have a long history of successful coexistence with television broadcasting.

Frequency coordination is mandatory for successful operation of large numbers of wireless microphones (such as the national political convention example given above). If interference problems require even a single frequency change during an event, the entire frequency coordination plan may have to be re-done. Logistically, this may be impossible during a live performance. Frequencies within a TV channel that are **not** in use by wireless microphone equipment are just as significant as those that are, since they are also part of the frequency compatibility plan. If a non-coordinated transmitter begins to operate on a previously unoccupied frequency, it can and will

interfere with multiple wireless microphone channels. **In the present context, this means that unlicensed devices should not start transmitting within a TV channel that is already in use by wireless microphones, even if a particular frequency within that channel appears to be unused.**

II. Unlicensed Devices Will Cause Harmful Interference to Wireless Microphones if the Commission Adopts the Rules as Proposed in the NPRM.

A. The NPRM's assumptions about wireless microphones do not hold up to scrutiny

The assumptions in the NPRM about wireless microphones will not guard against unlicensed device interference. In Paragraph 38 of the NPRM, the FCC acknowledged the presence of wireless microphones in the television band spectrum that would potentially be occupied by new unlicensed devices. However, the Commission expressed the view that interference from these devices would not be a problem due to the following stated assumptions:

- Wireless microphones are permitted to operate with the relatively high power of 50 mW on VHF and 250 mW on UHF frequencies
- Wireless microphones are used at relatively short working distances, and therefore deliver a strong signal to the receiver
- Wireless microphones use FM transmission, which exhibits a "capture effect" that rejects co-channel interference.[7]

Shure conducted several studies to determine whether or not these assumptions are valid and found several problems.

1**) The majority of wireless microphones do not use the maximum power allowed under Part 74 of the Commission's Rules**. Shure catalogued the power

[7] NPRM, ¶ 38.

ratings of 57 models currently offered by 12 major manufacturers that sell wireless microphone systems in the United States. The study revealed that less than 4% (2 models) operate at the FCC maximum power level of 250 mW, while the vast majority of models, 85% (49 models), operate between 10 mW and 50 mW of conducted output power. As discussed earlier, lower power design allows for simultaneous operation of more wireless systems within a given amount of spectrum, conserves battery life, and reduces equipment cost to the user by approximately 30% over time due to longer battery life. This information is presented in Figure 1 below.

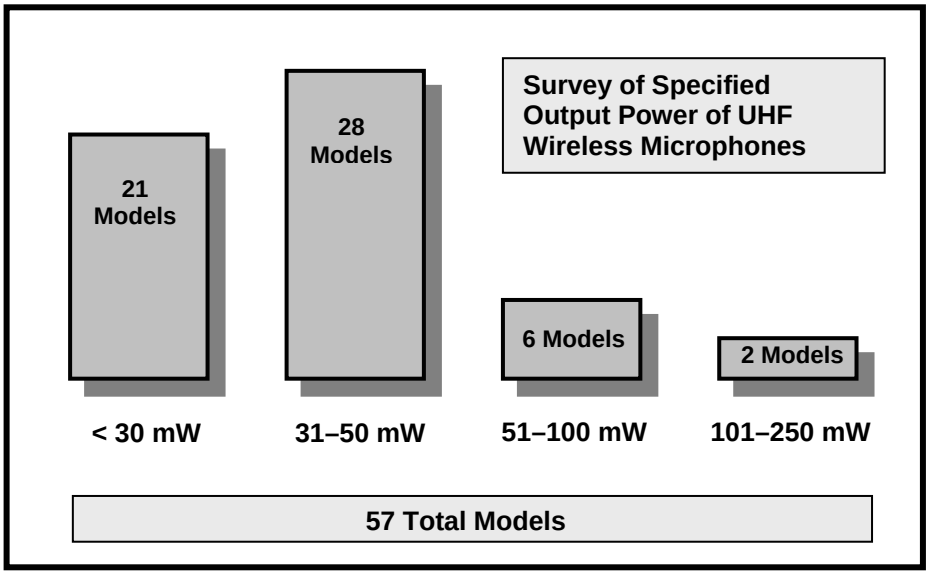

Figure 1. Wireless Microphone Output Power Survey

While most microphone models operate with less than 50 mW of conducted output power, the effective radiated power (ERP) of the transmitters is far lower due to antenna efficiency, body absorption and shadowing effects. Shure has studied the antenna efficiency and body absorption effects of wireless microphones using six

different models in both VHF (two models) and UHF (four models) at a working distance of 30 meters outdoors. We found that the average power loss beyond free space propagation varied between 10 dB and 25 dB for UHF and between 47 dB and 52 dB for VHF, as shown in Figure 2 below.[8]

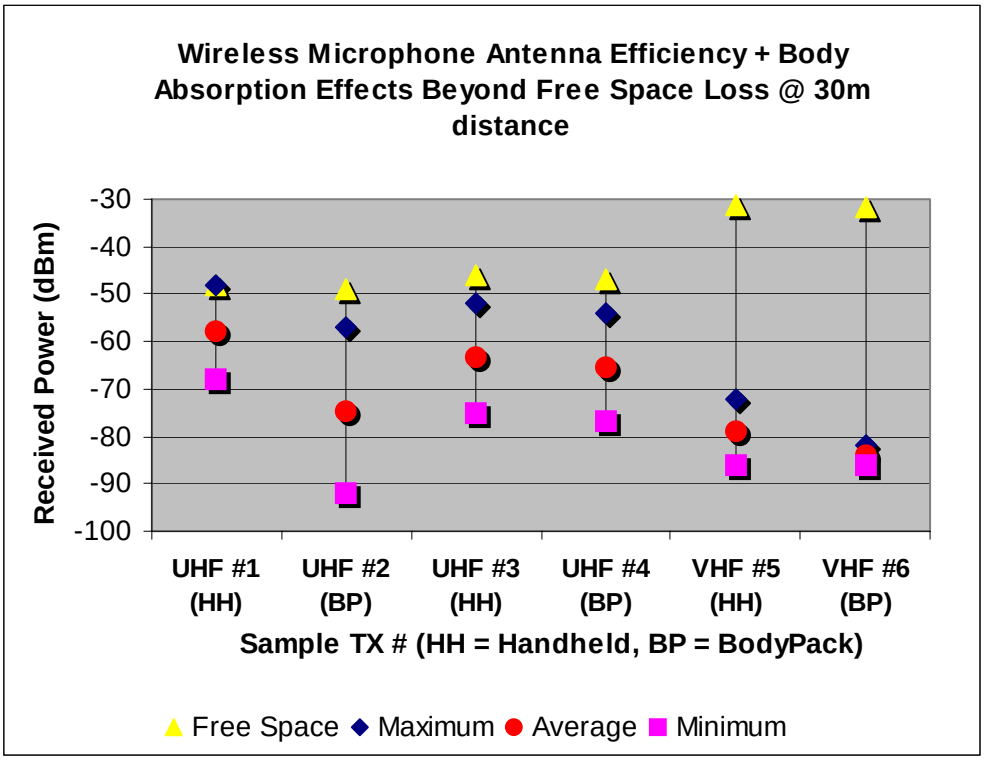

Figure 2. Wireless Microphone Antenna Efficiency And Body Absorption Study Results

We applied these attenuation measurements to typical wireless microphone transmitters at UHF and VHF to determine the effective radiated power. The results are summarized in Table 2 below.

[8] Even though the body absorption loss is high, the receiver is designed to accommodate this loss and still maintain a 100 meter working range in the absence of interference.

Wireless Microphone Type	Conducted Power Level of Transmitter (e.g.)	Attenuation Range Due to Body Absorption (from chart)	ERP of Transmitter (= Conducted Power – Attenuation)
UHF	10 mW (+10 dBm)	10 to 25 dB	1 mW to 0.03 mW (0 dBm to -15 dBm)
VHF	50 mW (+17 dBm)	47 to 52 dB	1 uW to 0.3 uW (-30 dBm to -35 dBm)

Table 2. Effective Radiated Power of Wireless Microphones

The net effect of body absorption and shadowing is to reduce effective radiated power, which in turn lowers the link margin[9] of the wireless microphone. A lower link margin raises the susceptibility of the system to interference.

2**) Even at relatively short distances, wireless microphones will experience co-channel interference from unlicensed devices**. Shure surveyed over 200 wireless microphone users to determine their expectations for working range. Although it is true that many users operate their systems at distances of 100 meters or less, some applications require use at distances of 200 meters or more. Sporting events and movie production fall into this category. However, even at an operating range of 100 meters, the link margin for these systems is relatively low. For professional audio, the minimum Desired–to–Undesired (D/U) signal ratio is 20 dB.[10] Shure conducted an extensive study involving tests of both indoor and outdoor propagation in order to determine the effect of multipath on the available link margin at a given distance. These tests involved more than 2,000 data points and included both handheld and body-pack wireless microphone transmitters. An example of the signal levels from handheld and body-pack

[9] Link margin may be defined as the amount that the D/U signal ratio exceeds the minimum required for acceptable operation under normal use conditions.

[10] The NPRM recognizes that "[w]hether or not interference occurs depends on the desired-to-undesired (D/U) signal ratio needed for acceptable service." NPRM, ¶ 30. The NPRM has D/U for TV signals, but not wireless microphones.

wireless microphone transmitters is presented in Figure 3 below.

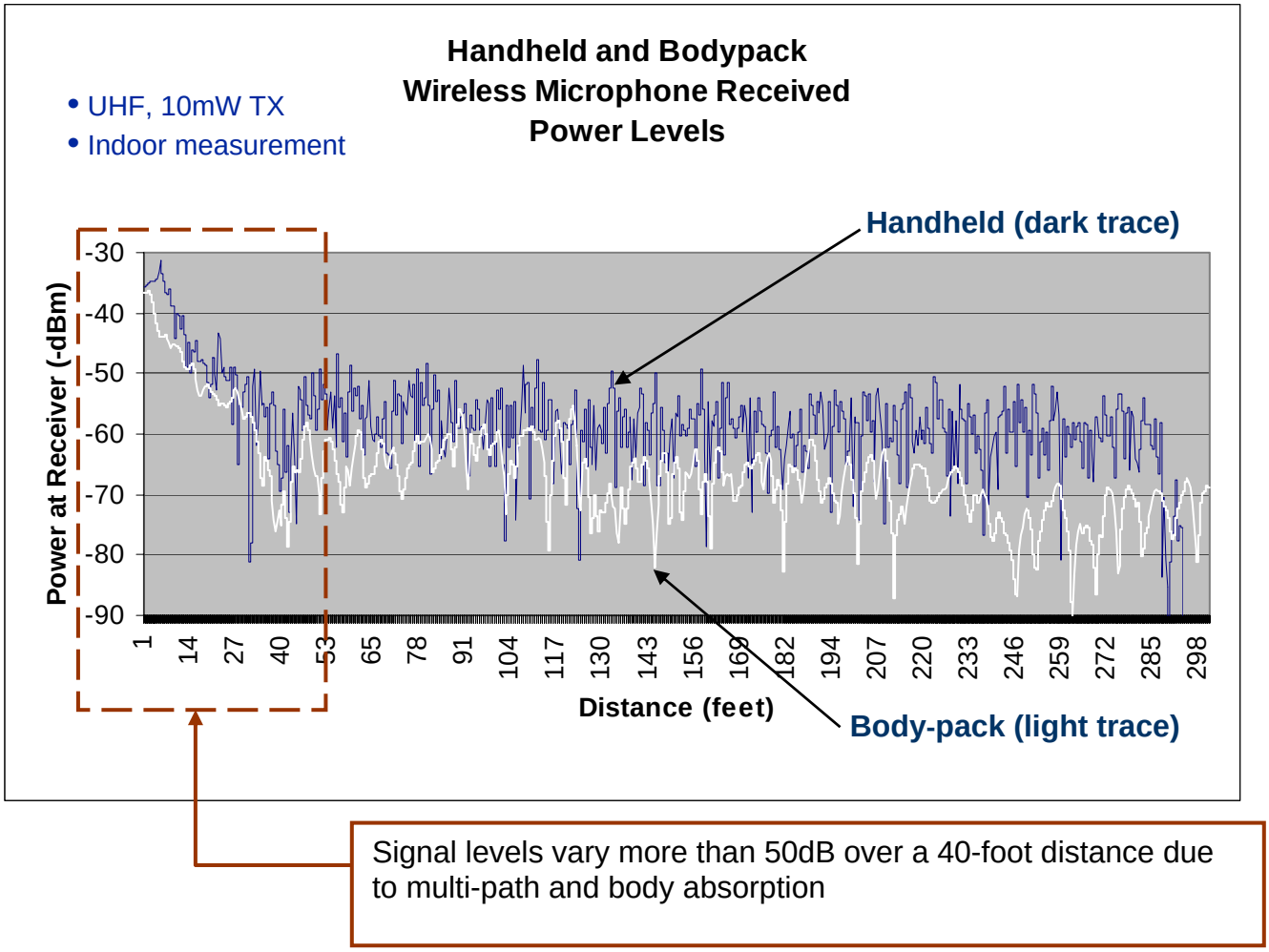

Figure 3. Wireless Microphone Signal Levels (Indoor) for Handheld and Body-pack Transmitters

It is apparent that in some cases, the D/U ratio approaches the minimum usable level at distances of only a few meters from the receiver. Diversity reception is widely used to mitigate this multipath fading by combining the signals from two antennas. However, it is important to note that this technique is only effective in the absence of co-channel interference. When interference is present, the receiver will tend to lock onto the interfering signal when it is stronger than the desired wireless microphone signal.

The conclusion of this study is that even at relatively short working distances, wireless microphones are vulnerable to co-channel interference from unlicensed devices.

3**) The FM capture effect is not a reliable protection without other safeguards.** The third assumption in the NPRM concerns the operation of the so-called "capture effect."[11] In FM transmission systems, the capture effect exhibits a "soft" transition, the exact nature of which depends on various system parameters. Using a test signal designed to simulate interference from the proposed unlicensed devices, Shure measured the capture effect for typical wireless microphone receivers. As mentioned previously, we determined that for interference-free operation, a Desired-to-Undesired (D/U) ratio of 20 dB or more is required. In other words, unless an interfering signal is at least 20 dB weaker than the wireless microphone signal, it will be audible. This 20 dB D/U ratio is explained by the fact that wireless microphones are limited by the Commission to 200 kHz of occupied bandwidth. A wider bandwidth would provide a better capture effect and improved sound quality with a lower noise floor, but as the capture effect is proportional to the modulation level *(i.e.*, occupied bandwidth), wireless microphones only derive a moderate amount of benefit from the FM capture effect[12] and cannot reject interference at D/U levels of less than 20 dB.

Due to the fact that co-channel interference will be noticeable for D/U levels of less than 20dB, new unlicensed devices will need to implement cognitive radio capability in order to operate in the TV broadcast spectrum without causing interference.

[11] NPRM, ¶ 38.

[12] Due to the restricted occupied bandwidth of wireless microphones, companding is used to achieve the signal-to-noise ratios required by broadcast professionals.

III. Shure's Experimental Interference Study Showed that Unlicensed Devices Will Interfere with Wireless Microphone Operations

Based on our findings concerning the assumptions in the NPRM, Shure concluded that unlicensed devices have the very real potential to adversely affect wireless microphones. We determined that the best way to find out would be to conduct dynamic "real world" tests of wireless microphone operation in the presence of co-channel interference. To accomplish this, Shure applied to the FCC for a Part 5 experimental license[13] that allows us to transmit a simulated unlicensed device signal on designated TV channels for the purpose of conducting interference tests. A block diagram of the equipment setup is shown in APPENDIX A. Two commercially available 802.11g Wi-Fi devices are configured as a peer-to-peer network. The output signal of one of these devices is sampled and fed to a mixer in order to translate its frequency to the desired UHF TV channel. The translated signal is then band-limited through a 5 MHz-wide band-pass filter, amplified to 100 mW, and then fed to a 0dBi omni-directional antenna. The majority of the tests involved co-channel operation of the interference source and the wireless microphone system.

Using the test setup described, Shure conducted interference tests at several indoor and outdoor locations and recorded the audio results. In one typical indoor arrangement, with the interference source, operating at 100 mW ERP, located 50 meters away from the wireless microphone receiver, noise and dropouts began to occur at distances of less than 5 meters between the wireless microphone transmitter and the

[13] Call Sign: WD2XKG, FCC File No. 0138-EX-PL-2004.

receiver. (The wireless microphone used for this test would normally operate noise-free up to 100 meters indoors without co-channel interference present.)

The results of this test can be predicted by performing a signal level analysis. At a distance of 50 meters, the power level seen from the unlicensed device at the wireless microphone receiver is approximately –54 dBm.[14] Adding the 20 dB D/U requirement to the received power level of –54 dBm gives a –34 dBm level. (This is the level the wireless microphone needs to have for interference-free operation.) The path loss can be calculated by subtracting the –34 dBm from +15 dBm wireless microphone transmit power which equals 49 dB. In a free space environment, 49 dB of path loss is achieved at a distance of approximately 10 meters. However, with a body-pack transmitter, 49 dB of path loss is seen at a nearer distance than 10 meters due to the body absorption attenuation reported in the earlier section. As was seen in the previous signal analysis in Figure 3, a signal level of –34 dBm is reached at just a few meters away from the wireless microphone transmitter. Therefore, the predicted interference distance matches the experimental results in this test.

These tests were designed and conducted to demonstrate the type and amount of interference that an unlicensed device will cause if it does not properly identify existing Part 74 users before transmitting. **These test results reinforce the need for unlicensed devices operating in the TV spectrum to implement cognitive radio functions and other interference mitigation measures to avoid causing interference to incumbents.**

[14] Received power level = +20 dBm (transmit power) – 62 dB (path loss over 50 meters) – 12 dB (bandwidth spreading factor of 5 MHz/300 kHz) = -54 dBm.

IV. Shure Proposes a Three-Part Interference Mitigation Solution

In this NPRM, the Commission requested comment on measures needed to protect wireless microphone operations.[15] Because of the unique challenges posed by the introduction of unlicensed devices in the TV spectrum and after study of multiple mitigation techniques, Shure believes that no single interference mitigation approach is adequate to solve all of the potential problems. The different use patterns discussed previously in Section I call for different mitigation techniques. Accordingly, we propose a solution that includes three complementary techniques that we believe will be effective in preventing unlicensed device interference to wireless microphones. **Shure asks that the Commission codify into its rules the three solutions as shown in Figure 4 and discussed below in order to ensure protection of wireless microphones.**

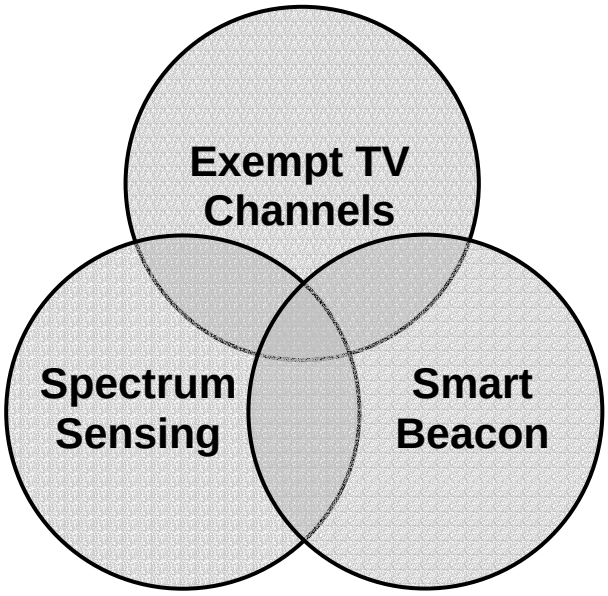

Figure 4. Interference Protection Solutions from Unlicensed Devices

[15] NPRM, ¶ 38.

A. The Commission should identify 6 TV Channels to be exempt from unlicensed device operations.

The FCC proposed that certain TV channels in each television market be designated as "exempt" from unlicensed device operation.[16] These channels would provide a "safe haven" for wireless microphones to operate without interference. Exempt TV channels would be a viable spectrum solution for many wireless microphone and wireless audio system users who need to operate a modest number of systems simultaneously in a particular location. These TV channels would also be valuable in large systems for critical wireless microphone channels that must be totally protected from interference; for example, channels to be used by the keynote speaker at a major television broadcast.

It is possible that the need for exempt TV channels may diminish over time as other interference mitigation techniques (including those discussed below) become viable. **However, at this time, no prototypes of unlicensed devices that incorporate spectrum sensing (also known as Dynamic Frequency Selection) have been built, and therefore no experiments demonstrating their ability to avoid interfering with wireless microphones have been conducted. Accordingly, it would not be prudent for the Commission to adopt rules that rely on unproven technology, not yet available to guard against interference to important existing operations.** With this in mind, Shure recommends that the Commission initially make available 6 exempt TV channels in each television market.

[16] NPRM, ¶ 38. The NPRM seeks comment on "designating one or two unused TV channels in each market for use only by wireless microphones." *Id.*

Several points should be considered in determining which TV channels should be considered for “exempt” status. Wireless microphones do not use the low VHF TV channels (2-6) because of ambient noise and antenna efficiency problems. Therefore, designating these channels as “exempt” from unlicensed device operation would not offer any benefit for wireless microphone users. Modern wireless microphone systems primarily operate in the UHF TV channels and in the high VHF TV channels (7-13). It is also important to note that wireless microphone systems are designed and sold for either VHF or UHF operation but not both. Thus, it would be desirable to have some exempt channels available in each band. Also, wireless microphone systems that are frequency agile typically have a tuning range of 18-24 MHz (3-4 TV channels). **With these facts in mind, Shure recommends that the Commission designate 2 VHF High Band TV channels (7-13) and 4 UHF TV channels in each television market as exempt from unlicensed device operation.** Shure is recommending this number of exempt channels based on two aspects of spectrum availability. First, it has been established that substantial amounts of unoccupied TV spectrum are available for rural broadband unlicensed operation across America today. Second, as the DTV transition is completed, analog TV stations will no longer be in operation, thus freeing up an approximate average of 4 UHF TV channels per market.[17] Therefore, even with a designation of 6 exempt TV channels (4 in UHF) as suggested by Shure, there should still be a significant amount of unoccupied TV spectrum available for unlicensed operations.

[17] Estimated for the top 50 U.S. TV markets after DTV repacking from DTV 52-69.

B. Unlicensed devices should be required to use spectrum sensing (a.k.a. Dynamic Frequency Selection) techniques

The ability of unlicensed devices to sample the spectrum and determine whether a particular TV channel is in use by a television broadcasting station or a wireless microphone could be a very efficient and useful means of preventing interference.[18] This technology, sometimes referred to as Listen Before Talk[19] (LBT) or Dynamic Frequency Selection (DFS), has been suggested in previous Commission proceedings. A major benefit of spectrum sensing is the fact that incumbent users would not need to buy or configure anything in order to continue using their equipment without interference.

However, in order for this technique to be truly effective in preventing harmful interference, two conditions must be met. The first condition is that all devices on the network must do spectrum sensing in a distributed, cognitive fashion. This technique harnesses the power of all devices on the network to effectively "sample" the signal environment at various physical locations and reduce the possibility of "hidden nodes" not being detected, which can result in harmful interference.

The second condition is that the interference range of the unlicensed "network" must not exceed its sensing range, i.e., the network must be able to sense the power levels of the incumbent signals throughout the entire coverage area of the unlicensed network. If the spectrum sensing function works as intended, the unlicensed device will detect incumbent users throughout the entire coverage area of the unlicensed network and avoid transmitting in TV channels that are in use. The main issue with spectrum

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[18] NPRM, ¶¶ 20, 28 (seeking comment on spectrum sensing as an interference mitigation technique).

[19] *See Revision of Parts 2 and 15 of the Commissions Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band*, ET Docket No. 03-122, *Report and Order* (released November 18, 2003) at 22.

sensing is whether or not a potential interferer would be able to detect a weaker wireless microphone signal. If the power level disparity is too great, the unlicensed device will not be able to sense and avoid the wireless microphone, and will interfere with it. **For this reason, Shure opposes the use of higher power levels than those proposed in the NPRM for unlicensed devices operating in the television broadcast bands.**[20]

Shure has conducted measurement studies to determine how far away a wireless microphone signal can practically be sensed outdoors using the proposed –107 dBm detection threshold that has been developed in the IEEE 802.18 Study Group.[21] These measurements were conducted at the Shure corporate facilities using standard VHF and UHF wireless microphone transmitters, omni-directional receiving antennas, and a portable spectrum analyzer. The omni-directional receiving antennas were placed at two locations on the roof of the Shure facilities at 13.7 meters and 31.1 meters above ground level.[22] Signal strength measurements were taken for both VHF and UHF, handheld and bodypack wireless microphone transmitters held and worn by a Shure associate outdoors at distances of 457 meters and 1200 meters from the receiving antenna. Diagrams of the measurement setups, distances and photographs of the environments are shown in APPENDIX B. The associate was initially positioned in a line-of-sight view of the receiving antenna and then slowly turned one revolution

[20] NPRM, ¶ 27 (seeking comment on whether higher power levels than proposed in the NPRM should be allowed).

[21] The detection threshold is defined as the received signal strength in dBm referenced to the output of a 0 dBi antenna.

[22] The Shure building complex has a split-level roof structure that allows antenna placement at two different heights. The area surrounding the Shure facilities is a mixed retail and industrial suburb with a mix of low-rise buildings and foliage. The measurements were taken during the day with normal automotive and pedestrian traffic present at ground level.

around to simulate normal motion while performing. The maximum and minimum signal levels were then recorded using the spectrum analyzer.

Although these measurements are not presented as a complete model for all environments and propagation paths, they are considered significant and are being presented here to help analyze the effectiveness of the spectrum sensing technique to wireless microphones. These measurements were conducted to determine the maximum sensing distance for a fixed/access type of network in a flat, suburban environment when the base station antenna is located at heights of 13.7 and 31.1 meters above ground level.[23] The signal levels for these measurements are summarized in Table 3 below.

Wireless Microphone Sensing Level Measurements (Outdoor-to-Outdoor)						
Wireless Microphone Type	**Sensing Distance**					
	1200 meters (13.7 meter RX antenna height)		**457 meters** (31.1 meter RX antenna height)		**1200 meters** (31.1 meter RX antenna height)	
	Max	Min	Max	Min	Max	Min
VHF HH (50 mW TX)	-113 dBm	-118 dBm	-95 dBm	-109 dBm	-103 dBm	-113 dBm
VHF BP (50 mW TX)	NF	NF	-104 dBm	NF	NF	NF
UHF HH (10 mW TX)	-96 dBm	-108 dBm	-70 dBm	-88 dBm	-88 dBm	-104 dBm
UHF BP (10 mW TX)	-98 dBm	NF	-70 dBm	-96 dBm	-93 dBm	NF

NF = Below Analyzer Noise Floor

Table 3. Spectrum Sensing Ranges for Wireless Microphones In Point-to-Multipoint Networks

The highlighted measurements indicate sensing distances and antenna heights

[23] There are other significant factors that lower the sensing range, such as indoor-to-outdoor propagation loss and irregular terrain environments, that have not yet been studied.

where the wireless microphone signal level is above the –107 dBm detection threshold and would be sensed by an unlicensed device. **Based on these tests, the practical maximum limit for sensing an outdoor wireless microphone from outdoor, fixed/access networks is approximately 300 meters for VHF and 1000 meters for UHF transmitters, using a 31 meter sensing antenna height.**

Even though spectrum sensing is useful for mitigating interference over relatively short distances, Shure concludes it is still an effective technique and should be required to protect wireless microphones.

C. Unlicensed devices must be able to recognize and avoid interference with a "Smart" beacon system in use for large events

If wireless microphones are operated outside the sensing ranges of the base station and CPE devices, the microphones will not be sensed by the network. The unlicensed network devices will then assume the TV channel is unoccupied and start transmitting causing co-channel interference to the wireless microphone. Since spectrum sensing is only effective over short distances, additional protection is required to extend over the entire coverage range of the unlicensed device network.

To provide guaranteed, real-time interference protection from unlicensed devices to wireless microphones over larger distances, Shure is proposing an extension to the spectrum sensing solution in the form of an RF "smart beacon." The Commission has previously proposed the use of a beacon system to facilitate spectrum sharing in a recent proceeding[24] and Shure believes this concept, appropriately adapted, can be used to protect incumbent users in the TV bands.

[24] *See Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies*, ET Docket No. 03-108, *Notice of Proposed Rulemaking and Order* (released December 30, 2003) at 57.

We propose that the beacon system be operated under the same restrictions and operating parameters as wireless microphones. The beacon would operate within one of the vacant TV channels being used by the wireless microphone system. It would continuously or periodically transmit information concerning the TV channels in use by the various wireless microphone and wireless audio systems in operation at that location. An unlicensed device searching for available TV spectrum would be required to scan for and detect the beacon signal, and decode the TV channel data. The unlicensed device would avoid operating in any TV channels marked as being in use by the beacon transmitter. Since the data from the beacon transmitter would only indicate the TV channels that are not permitted for use by unlicensed devices, there is no need for "handshaking" between the unlicensed devices and the beacon. Thus, the unlicensed device would only need to receive the beacon signal but not transmit a reply to the beacon.

The beacon would contain both a transmitter and receiver and use low-rate digital modulation*, e.g*. narrowband Frequency Shift Keying (FSK), which should be simple for an unlicensed device receiver to decode. The occupied bandwidth of the beacon must be kept very low to conserve spectrum and also allow the use of a narrow detection bandwidth at the unlicensed receiver, thereby improving sensitivity and enhancing sensing coverage back to the unlicensed device.

A preliminary beacon system is shown in Figure 5 below.

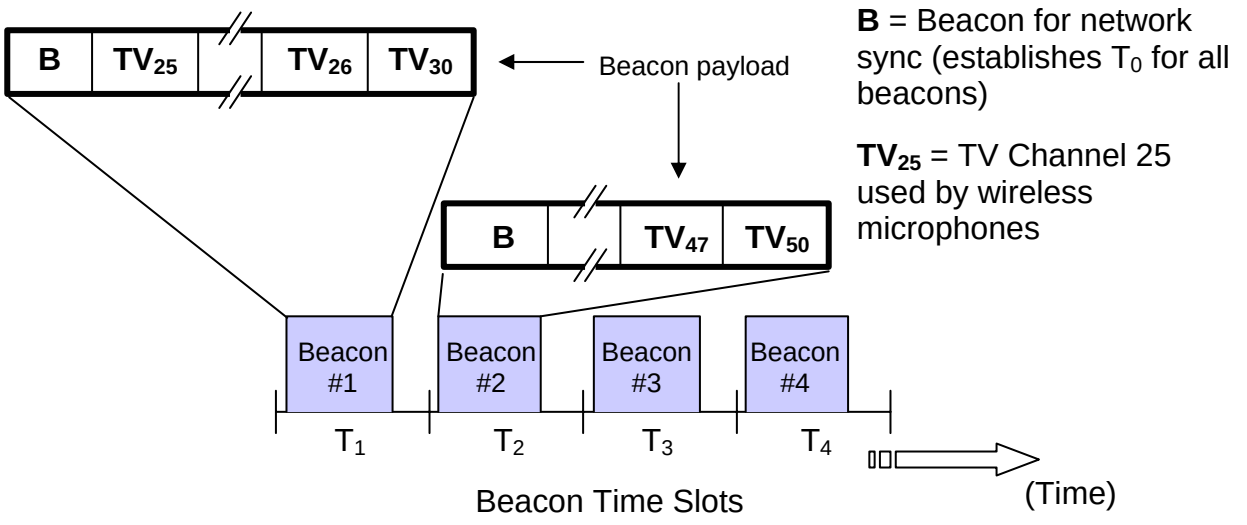

Figure 5. Beacon System Concept

Shure is suggesting a simple beacon protocol based on a Time Domain Multiple Access (TDMA) scheme that contains pre-determined time slots to allow more than one beacon to transmit multiple 'requests' on the same beacon frequency in the same local area.[25] This protocol is suggested for its low implementation cost and low complexity to both wireless microphone and unlicensed device manufacturers. This protocol also has the advantages of guaranteed time slots for low latency transmissions, robustness to inexpensive frequency timebase references and ad-hoc network coordination. This characteristic is required to allow more than one 'domain' of wireless microphone users to transmit from multiple beacons in the same area without corrupting the data from multiple transmissions on the same frequency – *e.g.* multiple news crews arriving to

[25] This network protocol is similar to that used in the IEEE 802.15.4 standard, "Wireless Medium Access Control (MAC) and Physical Layer Specifications (PHY) for Low-Rate Wireless Personal Area Networks (LR-WPANs)".

cover a breaking story at the same time or a large campus area such as the Olympic games.

Since the beacon network will need to support only a small number of nodes, a baud rate of less than 1000 bytes-per-second can be used keeping the occupied bandwidth low for spectrum sensing. The beacon system would also contain mechanisms for automatically establishing network coordination between multiple beacons (a.k.a. Personal Area Network coordinator function), data verification, and securing data transmissions against unauthorized uses.

We envision that a beacon RF transceiver could be deployed into a wireless microphone system in several ways. One possibility would be a “stand alone” transceiver that could be manually programmed with the occupied TV channel information by the wireless microphone system operator. This type would be a useful adjunct to legacy wireless microphone systems. Future wireless microphone systems could incorporate a built-in beacon transceiver, or they could be designed to automatically program the data channel of an external beacon. In practice, a wireless microphone system operator would set up the beacon and turn it on for the duration of the event for which protection is needed. At other times, the spectrum would be released for other purposes.

Shure sees the beacon system as a very efficient use of spectrum for protecting wireless microphones. The microphone beacon would only request the use of spectrum over a very localized area for a specific amount of time in contrast to a TV broadcast control signal that would obviously cover a large area, and would unnecessarily reserve spectrum over a greater distance than required. Therefore, Shure does not recommend

the use of a broadcast control signal for wireless microphone protection, except as one possible method of conveying “taboo” channel information about occupied TV channels or “exempt” wireless microphone TV channels to unlicensed devices.

In order for a beacon system to be a useful and efficient means of interference protection, Shure asks the Commission to define requirements in its rules for a standard beacon format to be used by all unlicensed devices operating in the TV spectrum.

Shure has proposed a three-part interference solution that will help mitigate the effects of interference from unlicensed devices operating in the television spectrum. The solution components include:

- Designating 6 “exempt” TV channels in each television market, in which unlicensed devices would not operate.
- Use of cognitive “spectrum sensing” techniques by unlicensed devices to prevent transmission in TV channels that are occupied by incumbent users, including television broadcasting stations, wireless microphones, and wireless audio systems.
- Use of an RF “smart beacon” transceiver to enhance the interference prevention capabilities of spectrum sensing at greater distances, as described above.

V. Shure Recommends Additional Operational and Technical Requirements to Implement Meaningful Interference Mitigation

Although the interference mitigation solutions proposed in Section IV provide the basic framework for protecting wireless microphones and wireless audio systems from

interference, additional technical and operational requirements are necessary for different classes of unlicensed devices. Shure has categorized these according to three types of systems:

- Fixed/Access Point-to-Multi Point ("P2MP") Systems
- Fixed/Access-to-Portable ("A2P") Systems
- Personal/Portable Peer-to-Peer ("P2P") Systems[26]

These requirements are explained in the sections below.

The additional interference mitigation recommendations are summarized in Tables 5 and 6 at the end of this section – "Operational Requirements" and "Technical Requirements."

A. Fixed Access Point-to-Multi Point (P2MP) systems

Fixed Access Point-to-Multi Point ("P2MP") networks consist of a Fixed/Access Point base station serving multiple fixed Customer Premise Equipment ("CPE") stations. A Wireless Internet Service Provider ("WISP") network represents a typical application for this configuration. In the NPRM, the Commission categorized these devices as "Class II" devices and proposed a power limit of 1 Watt conducted or 4 Watts EIRP.[27] Because of the high power level and high antenna height involved, these devices have greater potential to interfere with television reception and wireless microphone system operation over a much larger area than other types of unlicensed devices. Furthermore, it was shown in previous sections that spectrum sensing is only effective over relatively short distances and additional protections are needed to ensure interference-free

[26] The NPRM defines two broad classifications for unlicensed devices, Fixed/Access systems and Personal/Portable systems. NPRM, ¶ 19. Shure includes a hybrid class, fixed/access-to-portable systems.

[27] NPRM, ¶ 25.

operation over the entire range of the P2MP network. To mitigate the effects of interference from these higher power P2MP networks, Shure proposes the following operational requirements:

1. The Fixed/Access Point base station and the CPE stations must form a network of at least two devices in order to operate. The CPE must not transmit unless it receives a base station transmission instructing the CPE to join the network.
2. P2MP network operation should be limited to rural areas, which are defined in FCC Report & Order 04-220 as counties with a population density of 100 persons or less per square mile. These are the areas with not only the greatest need for wireless broadband service but also with the greatest amount of open television spectrum. Such areas also have the lowest potential for interference to other devices, due to the low population density.
3. P2MP devices must not operate on channels or in areas where interference will occur within the Grade B contour of a television station.
4. The Fixed/Access Point base station location (to within 10 meter accuracy), operating parameters, and operator contact information must be registered in a publicly accessible Internet database in order to provide a point of contact in the event of interference. This database could also include a listing of designated exempt channels for wireless microphones.[28]
5. The Fixed/Access Point base station must be professionally installed.[29] In this context, “professional installation” means that the equipment must be installed or inspected by a NARTE (National Association of Radio and Telecommunications

[28] *See* NPRM, ¶ 28.
[29] *See* NPRM, ¶ 26.

Engineers) certified EMC engineer, an SBE (Society of Broadcast Engineers) certified Professional Broadcast Engineer, a Registered Professional Engineer, or similarly qualified person.

6. The CPE may be installed by the end user. However, the operator of the wireless service being provided to the customer by the owner of the Fixed/Access Point base station must verify the proper operation of the CPE. This is to ensure that the installation will conform to system planning factors and be installed at a fixed, outdoor location so as to minimize interference, and also that it will comply with RF safety requirements to protect the public from harm.

In addition to the above operational constraints, Shure recommends the following technical requirements for Fixed/Access devices:

1. The maximum permissible power levels for these devices must not exceed the amounts proposed in the NPRM, *i.e*. 1 W conducted / 4W EIRP for both Fixed/Access (base) stations and CPE stations.

2. To prevent intermodulation distortion (IMD) interference to wireless microphones and TV receivers operating on adjacent channels, the power spectral density of the base station and CPE should be controlled to ensure that emissions are "noise like." In addition, the power output should be limited according to the following diagram Figure 6:

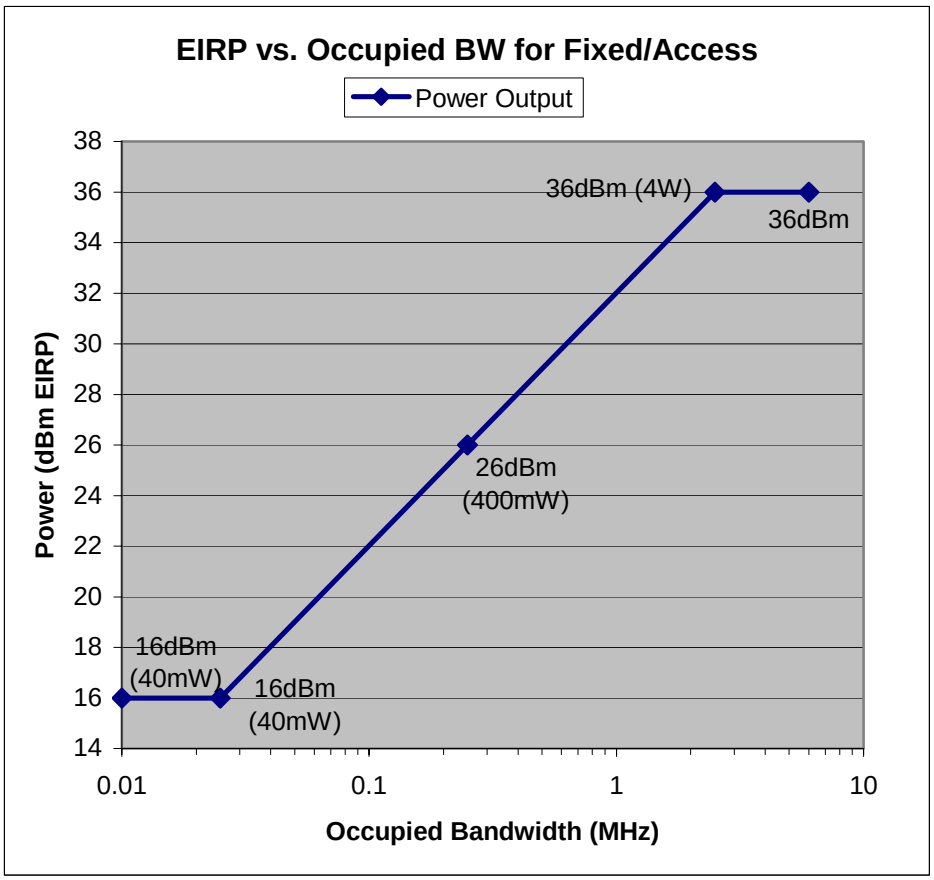

Figure 6. EIRP vs. Occupied BW for Fixed/Access Devices

3. The Fixed/Access Point base station antenna should be installed at a minimum height of 30 meters above ground level to minimize interference and maximize coverage range.
4. A CPE station antenna should be installed outdoors at a minimum

recommended height of 10 meters above ground level. Alternatively, the antenna should be mounted as high as possible and as far away from people and other electronic equipment as is practical. Under no circumstances should the antenna be located where humans may come into contact with it.

5. To minimize interference in unwanted directions, Shure recommends that the CPE transmitting antenna have a minimum specified directive gain of 14 dBi and a minimum specified front-to-back ratio of 15 dB at the operating frequency.
6. To minimize transmitting power, the CPE antenna should be oriented within 20 degrees (in both azimuth and elevation) of the strongest signal from the desired fixed Access Point base station transmitter.
7. The intentional radiated emissions of the base station and CPE devices must be confined to one or more contiguous TV channels as long as the emissions are independent from a modulation standpoint. This allows Frequency Division Duplex ("FDD") to be used in areas where more than one TV channel is vacant, but guarantees interference protection is maintained on a per-TV channel basis. This requirement is critical to allow for proper interference protection to new TV stations and itinerant wireless microphone and Part 74 operations.[30]
8. The radiated emissions of the base station and CPE devices that fall outside the TV channel where the devices operate must comply with the radiated emissions limits of §15.209(a).[31]

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[30] For example, if a Fixed/Access Point-to-Multipoint network is operating across two unoccupied TV channels and one of the TV channels is then used by a Part 74 service, that TV channel must be released by the fixed/access system but it can still operate on the remaining unoccupied TV channel. If the modulation extended across both TV channels and was not independent, then the Fixed/Access network would need to vacate both TV channels.

[31] The emissions limit in the UHF TV channel range is specified at 200uV/m measured at 3 meters. This equates to a received power level of approximately –85 dBm (at 650 MHz) 3 meters away from an

9. Both Fixed/Access Point and CPE devices must use spectrum sensing to continuously monitor their environment for the presence of wireless microphones both prior to and during operation. The unlicensed device must use an omni-directional sensing antenna of at least 0 dBi gain or greater. The detection threshold sensitivity must be -107 dBm or lower, within a 200 kHz bandwidth, for both analog and digital wireless microphones. If the Fixed/Access Point base station antenna is co-located with other communications systems such that receiver sensitivity is adversely affected, the operator may choose to deploy one or more sensing receivers at alternative locations within 1 km of the transmission point and ensure the sensing receiver is capable of achieving the detection threshold. These receivers shall join the wireless network and report the presence of other services operating in the occupied channel. The proposed spectrum sensing ("DFS") parameters are summarized in the following Table 4:

unlicensed device. A co-channel power level of –85 dBm is enough to cause interference to a wireless microphone. Emission levels greater than § 15.209(a) should not be allowed for new unlicensed devices operating in the TV bands.

DFS Parameter for Wireless Microphones	Value
Channel Availability Check Time	30 sec
Non-Occupancy Period	60 minutes
Channel Detection Time	500 msec
Channel Setup Time	2 sec
Channel Opening Transmission Time (Aggregate transmission time)	100 msec
Channel Move Time (In-service monitoring)	2 sec
Channel Closing Transmission Time (Aggregate transmission time)	100 msec
Interference Detection Threshold	-107 dBm

Table 4. DFS Parameters for Wireless Microphone Identification and Protection

This proposed dynamic frequency selection model is based on that which was ordered in the recent 5 GHz proceeding.[32] The model has been extended with new variables and behaviors that are appropriate and required for protecting Part 74 devices. Shure notes that these values may be reviewed as the model is studied in more detail throughout this proceeding. For more detail and definition of the DFS model terminology, see APPENDIX C.

10. Both Fixed/Access Point base stations and CPE devices must periodically scan for and detect a beacon signal that indicates which TV channels are in use by Part 74 devices in that area. The scanning time for the beacon signal would only

[32] *See Revision of Parts 2 and 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5GHz Band*, ET Docket No. 03-122), *Report and Order*, FCC 03-287 (released November 18, 2003) at 22

need to be on the order of once per minute, instead of the continuous nature of spectrum sensing.

11. Both Fixed/Access Point base stations and CPE devices must be required to use dynamic transmitter power control ("TPC") to reduce the amount of transmitted power by at least 6 dB below the mean EIRP value when the maximum EIRP transmit power is not needed for adequate link margin.
12. Fixed/Access base stations should be required to automatically and periodically transmit a unique identification signal using a published, standard format.
13. To discourage abuse, the Commission should consider imposing a requirement that the CPE transceiver be integrated with the antenna. This would make it more difficult for end users to install booster amplifiers that would increase interference potential. It would also eliminate transmission line losses, allowing the transmitter to use less power.
14. When no vacant TV channels are available, all devices on the network must cease transmissions.

Fixed/Access-to-Portable ("A2P") systems

Fixed/Access-to-Portable systems consist of a Fixed/Access Point station serving multiple portable systems, as exemplified by itinerant operation of laptop computers with wireless "hot spots" in the 2.4 GHz band. This configuration represents a hybrid use of the Fixed/Access and Personal/Portable devices referred to in the NPRM. Shure believes that the power levels proposed in the NPRM should apply to devices used in this configuration when they are operated in defined rural area, *e.g*. the Fixed/Access

stations should be limited to 1 Watt conducted or 4 Watts EIRP,[33] and the Personal/Portable devices should be limited to 100 mW EIRP.[34] In addition, Fixed/Access devices would also need to meet all of the other operational and technical requirements for these stations (see above). **If operated outside of defined rural areas, Fixed/Access devices should be subject to the same power limits as the Personal/Portable device class, *i.e.*, 100 mW EIRP.**

In addition, for Fixed/Access Point stations operating outside of defined rural areas to provide a wireless "hot spot" service to Personal/Portable devices, Shure proposes the following operational requirements:

1. The Fixed/Access Point station and the Personal/Portable stations must form a network in order to operate. One-way transmission is not permitted. The purpose of this requirement is to mitigate against "hidden node" problems by requiring more than one unlicensed device to sense the presence of licensed systems.
2. Fixed/Access-to-Portable systems must not operate on channels or in areas where interference will occur within the Grade B contour of a television station.
3. The Fixed/Access Point station must be registered in a publicly accessible database in order to provide a point of contact in the event of interference. This database could also include a listing of designated exempt channels for wireless microphones.[35]
4. The Fixed/Access Point station must be professionally installed. In this context, "professional installation" means that the equipment must be installed or inspected by a NARTE certified EMC engineer, an SBE certified Professional

[33] *See* NPRM, ¶ 25.
[34] *See* NPRM, ¶ 22.
[35] *See* NPRM, ¶ 28.

Broadcast Engineer, a Registered Professional Engineer, or similarly qualified person.[36]

In addition to the above operational constraints, Shure recommends the following technical requirements:

1. The maximum permissible power levels should not exceed 100 mW EIRP for Fixed/Access Point devices located outside defined rural areas, and 100 mW EIRP for Personal/Portable devices.
2. The Fixed/Access system must comply with the power spectral density requirements outlined for the P2MP class as previously discussed. The personal/portable devices must comply with the power spectral density requirements outlined in the P2P class as is discussed in the next section.
3. The Fixed/Access Point station antenna should be mounted as far away from people and other electronic equipment as is practical. Under no circumstances should the antenna be located where humans may come into contact with it.
4. Both Fixed/Access Point and personal/portable devices must use spectrum sensing to continuously monitor their environment for the presence of wireless microphones both prior to and during operation. The unlicensed device must use an omni-directional sensing antenna of at least 0 dBi gain or greater. The threshold sensitivity must be -107 dBm or lower within a 200 kHz bandwidth. If the Fixed/Access Point antenna is co-located with other communications systems such that receiver sensitivity is adversely affected, the operator may choose to deploy one or more sensing receivers at alternative locations within 1

[36] *See* NPRM, ¶ 26.

km of the transmission point and ensure the sensing receiver is capable of achieving the detection threshold. These receivers shall join the wireless network and report the presence of other services operating in the occupied channel. The proposed spectrum sensing (DFS) parameters are the same as for the P2MP class previously discussed and further outlined in APPENDIX C.

5. Both Fixed/Access Point base stations and personal/portable devices must periodically scan for and detect a beacon signal that indicates which TV channels are in use by Part 74 devices in that area. The scanning time for the beacon signal would only need to be on the order of once per minute, instead of the continuous nature of spectrum sensing.
6. Both Fixed/Access Point base stations and CPE devices must be required to use dynamic transmitter power control ("TPC") to reduce the amount of transmitted power by at least 6 dB below the mean EIRP value when the maximum EIRP transmit power is not needed for adequate link margin.
7. The intentional radiated emissions of the base station and CPE devices must be confined to one or more contiguous TV channels as long as the emissions are independent from a modulation standpoint. This allows Frequency Division Duplex ("FDD") to be used in areas where more than one TV channel is vacant, but guarantees interference protection is maintained on a per-TV channel basis. This requirement is critical to allow for proper interference protection to new TV stations and itinerant wireless microphone and Part 74 operations.
8. The radiated emissions of the base station and CPE devices that fall outside the TV channel where the devices operate must comply with the radiated emissions

limits of §15.209(a).[37]

9. Fixed/Access base stations should be required to automatically and periodically transmit a unique identification signal using a published, standard format.[38]
10. To discourage abuse, the Commission should require that Personal/Portable devices use integrated antennas. This would make it more difficult for end users to install booster amplifiers or external antennas that would increase interference potential.
11. When no vacant TV channels are available, all devices on the network must cease transmissions.

Personal/Portable Peer-to-Peer ("P2P") systems

Personal/Portable Peer-to-Peer systems consist of one or more Personal/Portable devices operating as a network to transfer data over short distances. Although these devices may operate with lower power than Fixed/Access devices, they do not necessarily have lower interference potential because of the way they will be used. It is expected that these devices would be widely deployed within the home and also within public places, with virtually no control over where they could be used. This means that they would be very likely to operate in close proximity to television receivers, cable set-top boxes and other types of wireless equipment, such as wireless microphones. For this reason, Shure believes that the 100 mW EIRP level proposed in the NPRM should be the maximum allowed for Personal/Portable devices.[39]

Furthermore, operation at 100 mW EIRP assumes implementation of all other

[37] *See* NPRM, ¶ 39.
[38] *See* NPRM, ¶ 25.
[39] *See* NPRM, ¶ 22.

interference mitigation techniques suggested in these comments. If the Commission does not adopt the suggested interference mitigation measures, the power limit should be significantly lowered.

To mitigate the effects of interference from P2P networks, Shure proposes the following operational requirements:

1. The Personal/Portable devices must form a network in order to operate. One-way transmission is not permitted. The purpose of this requirement is to mitigate against "hidden node" problems by requiring more than one unlicensed device to sense the presence of licensed systems.
2. Personal/Portable devices must not operate on channels or in areas where interference will occur inside the Grade B contour of a television station.

In addition to the above operational constraints, Shure recommends the following technical requirements:

1. The maximum permissible power levels must not exceed 100 mW EIRP for Personal/Portable devices.
2. To prevent intermodulation distortion ("IMD") interference to wireless microphones and TV receivers operating on adjacent channels, the power spectral density of personal/portable devices should be controlled to ensure that emissions are "noise like." In addition, the power output should be limited according to the following diagram Figure 7:

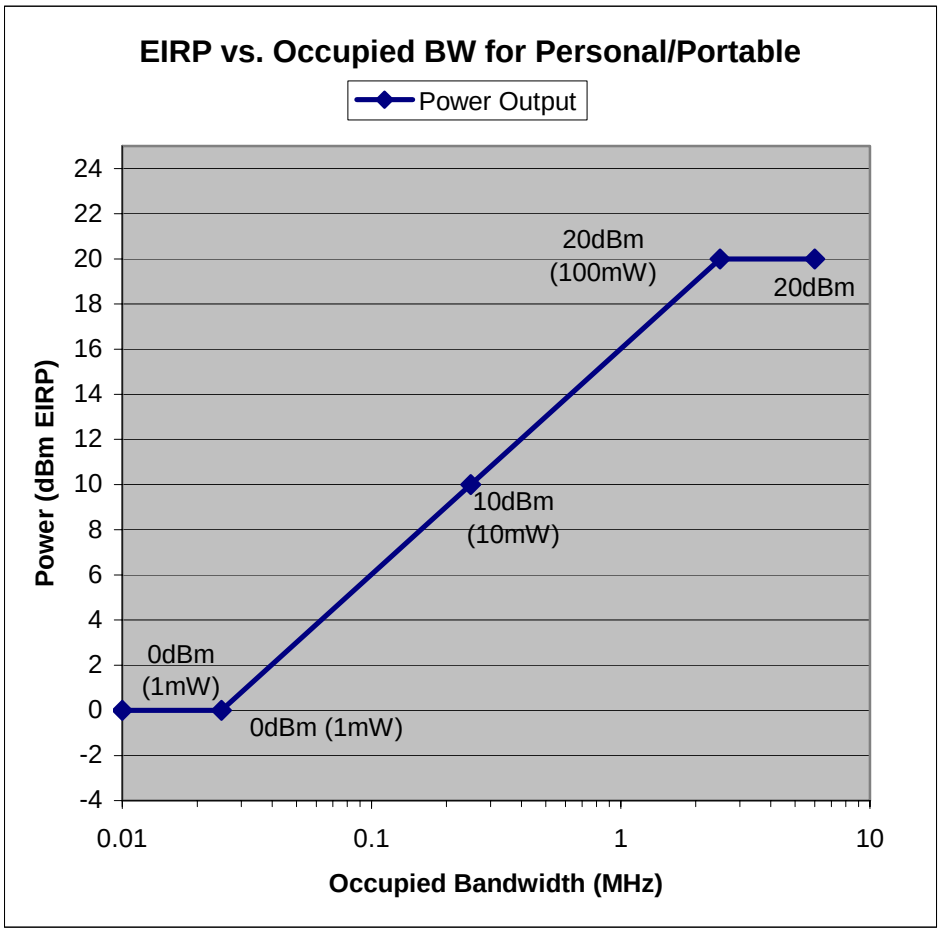


Figure 7. EIRP vs. Occupied BW for Personal/Portable Devices

3. Personal/portable devices must use spectrum sensing to continuously monitor their environment for the presence of wireless microphones both prior to and during operation. The unlicensed device must use an omni-directional sensing antenna of at least 0 dBi gain or greater. The threshold sensitivity must be -107 dBm or lower within a 200 kHz bandwidth. The proposed spectrum sensing ("DFS") parameters are the same as for the P2MP class previously discussed and outlined in APPENDIX C.
4. Personal/portable devices must periodically scan for and detect a beacon signal that indicates which TV channels are in use by Part 74 devices in that area. The

scanning time for the beacon signal would only need to be on the order of once per minute, instead of the continuous nature of spectrum sensing.

5. Personal/portable devices must be required to use dynamic transmitter power control ("TPC") to reduce the amount of transmitted power by at least 6 dB below the mean EIRP value when the maximum EIRP transmit power is not needed for adequate link margin.
6. The intentional radiated emissions of the base station and CPE devices must be confined to one or more contiguous TV channels as long as the emissions are independent from a modulation standpoint. This allows Frequency Division Duplex ("FDD") to be used in areas where more than one TV channel is vacant, but guarantees interference protection is maintained on a per-TV channel basis. This requirement is critical to allow for proper interference protection to new TV stations and itinerant wireless microphone and Part 74 operations.
7. The radiated emissions of the base station and CPE devices that fall outside the TV channel where the devices operate must comply with the radiated emissions limits of §15.209(a).[40]
8. To discourage abuse, the Commission should require that Personal/Portable devices use integrated antennas. This would make it more difficult for end users to install booster amplifiers or external antennas that would increase interference potential.
9. When no vacant TV channels are available, all devices on the network must cease transmissions.

[40] *See* NPRM, ¶ 39.

The Additional Interference Mitigation Recommendations discussed in Section V are summarized for convenience in the following two Tables 5 and 6 – “Operational Requirements” and “Technical Requirements.”

Table 5. Additional Interference Mitigation Recommendations – **Operational Requirements**

	OPERATIONAL Requirement	**P2MP** (Fixed/Access Point-to-Multi Point)	**A2P** (Fixed/Access-to-Portable)	**P2P** (Personal/Portable)
OPERATIONAL	**Networked**	All devices must form a network (of at least 2) in order to operate. One-way transmission or continuous transmitting is not permitted without a connection to another device.		
		CPE devices may not transmit unless they receive a fixed/access transmission instructing them to join the network.	Personal/portable devices may not transmit unless they receive a fixed/access transmission instructing them to join the network.	Only one device on the network can initiate transmission to other personal/portable devices after spectrum sensing.
	Broadcast TV Protection	Devices must not operate on TV channels or in areas where interference will occur within the Grade B contour of a television station.		
	Installation	Fixed/Access base stations must be professionally installed.		No installation required.
		CPE devices may be user-installed but verified by network operator.	No installation required for personal/portable devices.	
	Operating Location	Network operation is limited to rural areas as defined in Report & Order 04-220 as areas with less than 100 persons per square mile.	Network operation is limited to defined rural areas. If operated outside defined rural areas, the Fixed/Access EIRP reduces to 100 mW	No operating location limits required.
	Database Registration	Fixed/Access base station location, operating parameters, and operator contact information must be registered in a publicly accessible database.		No registration required.
		No registration required.	No registration required.	

Table 6. Additional Interference Mitigation Recommendations **– Technical Requirements**

	TECHNICAL Requirement	**P2MP** (Fixed/Access Point-to-Multi Point)	**A2P** (Fixed/Access-to-Portable)	**P2P** (Personal/Portable)
TECHNICAL	**Effective Radiated Output Power**	4W EIRP for both Fixed/Access and CPE devices.	4W EIRP for Fixed/Access devices when operated in defined rural areas; 100mW EIRP when used outside defined rural areas.	100mW EIRP for all personal/portable devices.
			100mW EIRP for all personal/portable devices.	
	Output Power Spectral Density	Fixed/Access and CPE devices: See Figure 6.	Fixed/Access devices: See Figure 6.	See Figure 7.
			Personal/portable devices: See Figure 7.	
	Transmitting Antenna Parameters	Fixed/Access antenna installed at 30 meters or greater above ground level.	Fixed/Access antenna installed out of the reach of humans and as high as possible.	Personal/portable antennas must be integral to the device with an omni-directional gain of 0 dBi.
		CPE antenna installed outdoors, at 10 meters or greater above ground level. CPE antennas should be oriented toward direction of the strongest signal from the Fixed/Access base station within 20 degrees. CPE antennas must have a directive gain of 14 dBi and a front-to-back ratio of at least 15 dB. CPE antennas must be integrated with the transceiver.	Personal/portable antennas must be integral to the device with an omni-directional gain of 0 dBi.	
	Sensing Antenna Parameters	Fixed/Access and CPE devices must have a sensing antenna that is omni-directional with a gain of at least 0 dBi or greater.	Fixed/Access devices must have a sensing antenna that is omni-directional with a gain of at least 0 dBi or greater.	Personal/portable devices must have a sensing antenna that is omni-directional with a gain of at least 0 dBi or greater.
			Personal/portable devices must have a sensing antenna that is omni-directional with a gain of at least 0 dBi or greater.	

	TECHNICAL Requirement	**P2MP** (Fixed/Access Point-to-Multi Point)	**A2P** (Fixed/Access-to-Portable)	**P2P** (Personal/Portable)
	Multiple TV Channel Transmissions	The intentional radiated emissions from all devices must be confined to one or more contiguous, unoccupied TV channels as long as the emissions are independent from a modulation standpoint. Interference protection must remain on a per-TV channel basis.		
	Radiated Emissions	The radiated emissions from all devices that fall outside the TV channel of operation must comply with the radiated emission limits of § 15.209(a).		
	Spectrum Sensing	All devices must use spectrum sensing to continuously monitor their environment for the presence of wireless microphones both prior to and during operation. All devices must use a detection threshold of –107dBm for wireless microphones within a 200kHz bandwidth. See APPENDIX C for DFS parameters and analysis.		
	Beacon Signal	All devices must periodically scan for and detect a beacon signal that indicates which TV channels are in use by Part 74 devices in that area. The scanning time for the beacon signal would only need to be on the order of once per minute, instead of the continuous nature of spectrum sensing.		
	Transmit Power Control (TPC)	All devices must be required to use dynamic transmitter power control (TPC) to reduce the amount of transmitted power by at least 6 dB below the mean EIRP value when the maximum EIRP transmit power is not needed for adequate link margin.		
	Identification Signal	All Fixed/Access devices must automatically and periodically transmit a unique identification signal using a published and standard format.	All Fixed/Access devices must automatically and periodically transmit a unique identification signal using a published and standard format.	No identification signal required for personal/portable devices.
		No identification signal required for CPE devices.	No identification signal required for personal/portable devices.	

VI. The Commission Should Use a Phased Approach to the Introduction of Unlicensed Devices Operation in the TV Bands

At this point, very little experimental work has been done to demonstrate the efficacy of any of the interference mitigation techniques that have been proposed by the various interested parties. For example, no prototypes have been built or tested in “real world” situations to show how well dynamic spectrum sensing would work to protect television reception or the operation of wireless microphones and wireless audio systems within the TV bands. On the other hand, as previously described, Shure has experimentally verified the nature and extent of interference to wireless microphones that **would occur** if the proposed mitigation techniques were ineffective, or were not applied. Other interested parties have also conducted their own interference tests of a similar nature. In addition, the IEEE 802.18 RR-TAG has been considering what requirements should be placed on unlicensed operation in the TV bands.

Shure believes that it would **not** be prudent for the Commission to immediately authorize all types of unlicensed operation in the television bands with only minimal restrictions, without waiting for the standards process to complete or at least better inform the decision process with more concrete analysis and recommendations. There are several reasons for this concern. First, the TV bands are already occupied by critically important licensed services that the public relies on very heavily. Second, several Commissioners have already noted the importance of a successful transition from analog to digital TV and Shure believes that the potential for adverse interference to existing users -- including TV operations – could undermine consumer confidence and further complicate the DTV transition. Third, once deployed in the hands of the public, unlicensed devices will be very difficult to control or recall in the event that there

are interference problems. Accordingly, Shure recommends that the Commission take a phased approach to the introduction of new unlicensed services in the TV bands. For example, the Commission could initially authorize the Point-to-Multi Point ("P2MP") service for operation in defined rural areas. This would help bring broadband wireless Internet service to those parts of the country where it is most needed and where viable alternatives are not available. In addition, as noted previously, the potential for interference is probably lowest in these areas.

Due to time constraints, the IEEE 802.18 RR-TAG Study Group has limited its work to only studying the issues of unlicensed Point-to-Multi Point ("P2MP") operation for rural deployment. The other operational scenarios will have to be addressed by future work groups. Again, it must be stressed that all of the work to date has been based on theoretical calculations and models, together with limited test data. No actual systems have been tested.

In any case, the Commission should **only** allow new unlicensed devices to be placed on the market **after** extensive testing has demonstrated that they do not interfere with existing licensed services. This will require interactive development of test procedures and requirements with the industry and other affected parties, and preferably should involve an "open" testing process with independent observers. Shure is willing to support this process by participating in these tests.

Shure believes the rules proposed in the NPRM will not adequately protect licensed incumbent services, and that the technical and operational safeguards presented in these Comments represent the bare minimum that should be required in order to proceed with opening the TV bands to unlicensed use. **These safeguards**

must be codified in any new rules that the Commission issues, because voluntary compliance with industry standards will not be sufficient to protect incumbent users.

In addition, Shure recommends that the Commission defer allowing approval of unlicensed devices under these rules by Technical Certification Bodies (TCB's) for a period of two years.[41] This will afford an opportunity for the Commission to identify any unforeseen issues with these devices and is consistent with actions taken in similar rulemaking proceedings.[42]

[41] *See* NPRM, ¶ 45.

[42] *See Authorization and Use of Software Defined Radios*, ET Docket No. 00-47, First Report and Order, FCC 01-264 (released Sept. 14, 2001) (preventing TCBs from authorizing software defined radios for 6 months after the effective date of the order).

VII. Conclusions and Recommendations

We share the Commission's desire to increase the amount of spectrum available for unlicensed use by the public. However, reliable high-quality broadcast service and the creation of broadcast content is also vitally important to the American public, particularly in times of local or national emergency. Accordingly, broadcast spectrum must be protected from any possibility of harmful interference. Wireless microphones and other secondary users of television spectrum that are vital to broadcast program production are especially vulnerable to interference from unlicensed wireless devices, and practical means of protecting them are still under development. No prototypes have been built or tested in "real world" situations to show how well dynamic spectrum sensing would work to protect television reception or the operation of wireless microphones and wireless audio systems within the TV bands. On the other hand, as previously described, Shure has experimentally verified the nature and extent of interference to wireless microphones that **would occur** if the proposed mitigation techniques were ineffective, or were not applied.

The introduction of new unlicensed devices in the television broadcast bands must be done carefully to avoid causing interference problems on a grand scale. In these comments, we have recommended a three-part solution for mitigating interference to wireless microphones:

- Designate 6 "exempt" TV channels in each television market, in which unlicensed devices would not operate.
- Use of cognitive "spectrum sensing" techniques by unlicensed devices to prevent transmission in TV channels that are occupied by incumbent users,

including television broadcasting stations, wireless microphones, and wireless audio systems.

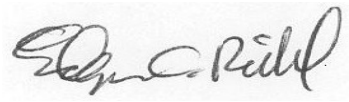
- Use of an RF “smart beacon” transceiver to enhance the interference prevention capabilities of spectrum sensing at greater distances, as described above.

In addition to these primary techniques, Shure has made specific recommendations of operational and technical requirements that we believe will further help to prevent interference from unlicensed devices to incumbent users of the television broadcasting spectrum.

Respectfully submitted,

SHURE INCORPORATED

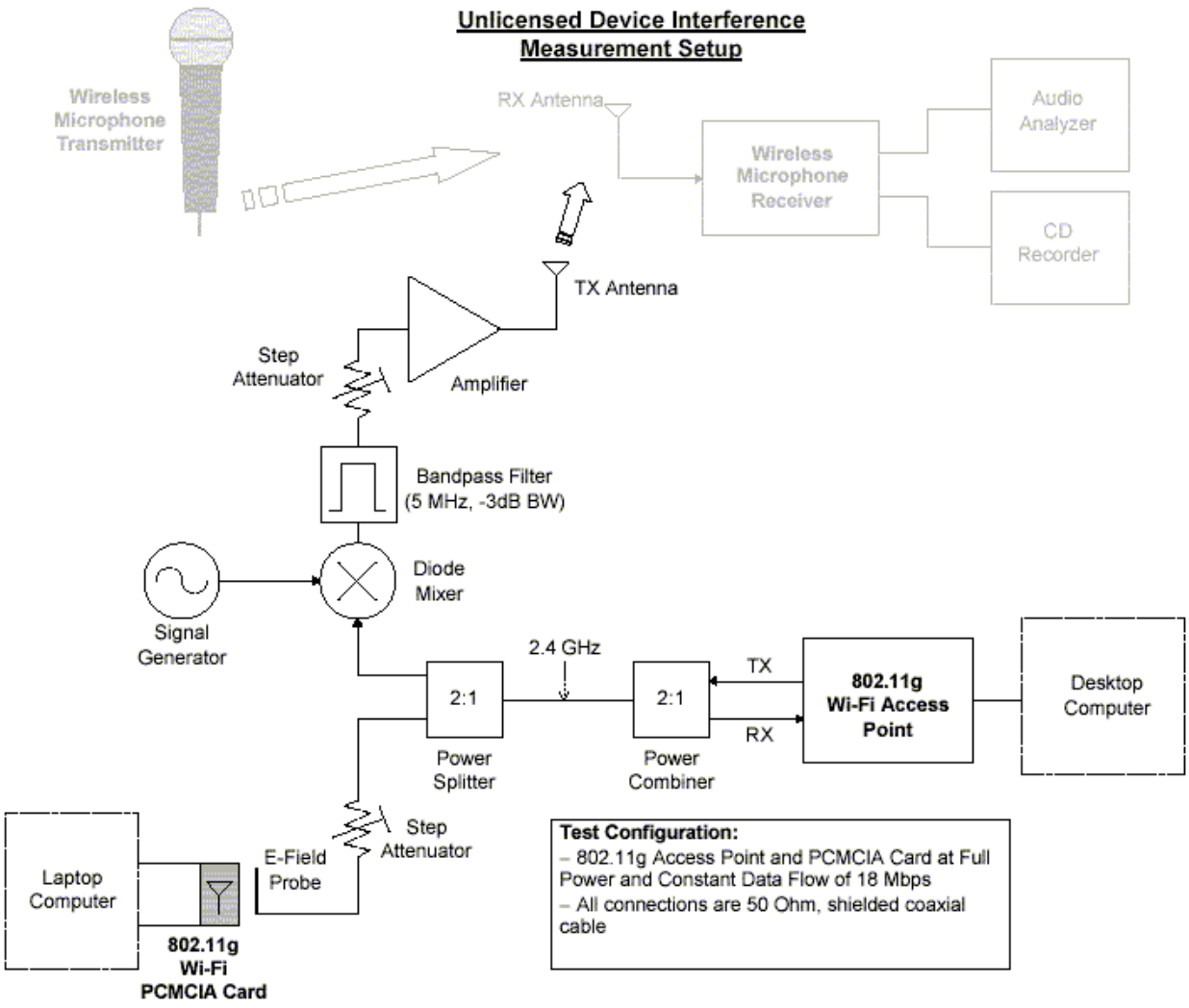
Ahren J. Hartman
Principal Engineer,

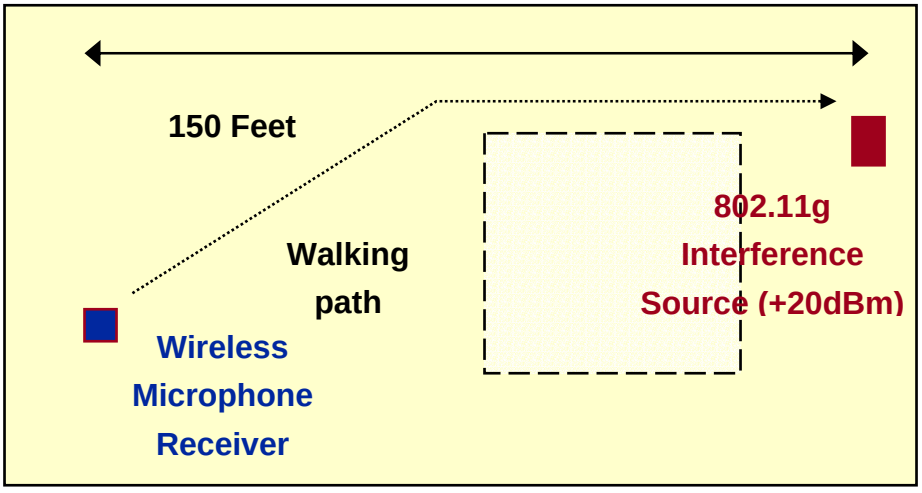


Edgar C. Reihl, P.E.
Principal Engineer
Shure Incorporated
5800 Touhy Avenue
Niles, IL 60714-4608

Catherine Wang
Jeanne Stockman
Swidler Berlin Shereff Friedman, LLP
3000 K Street, N.W., Suite 300
Washington DC 20007
November 30, 2004

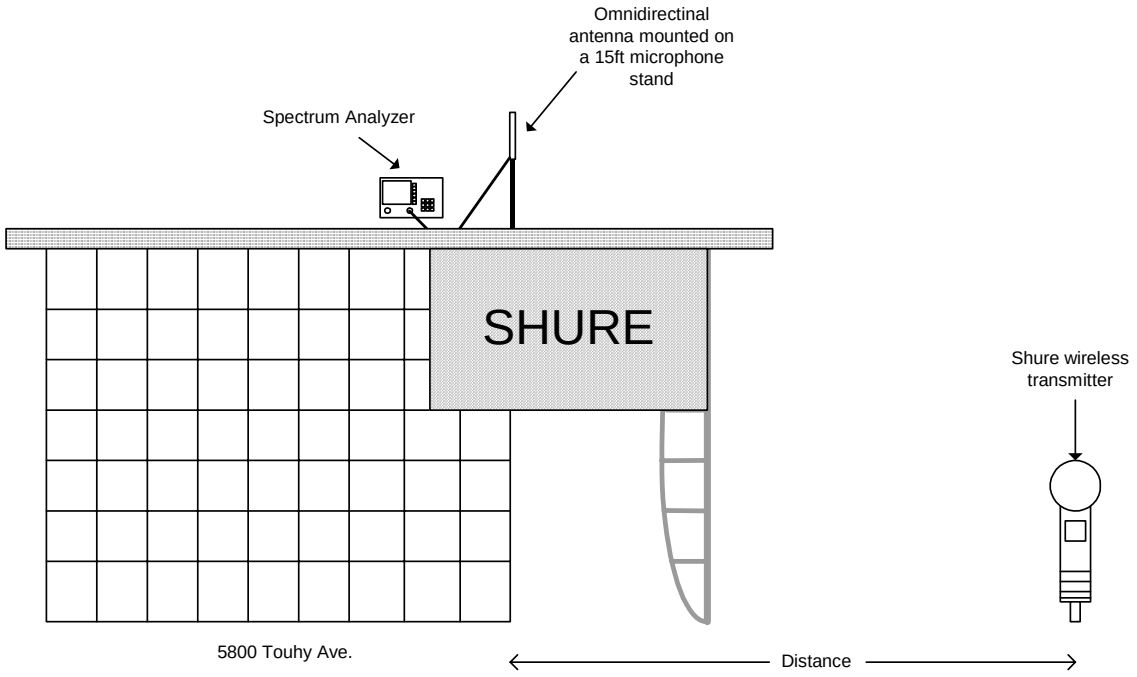
APPENDIX A: Unlicensed Device Interference Testing Equipment Setup



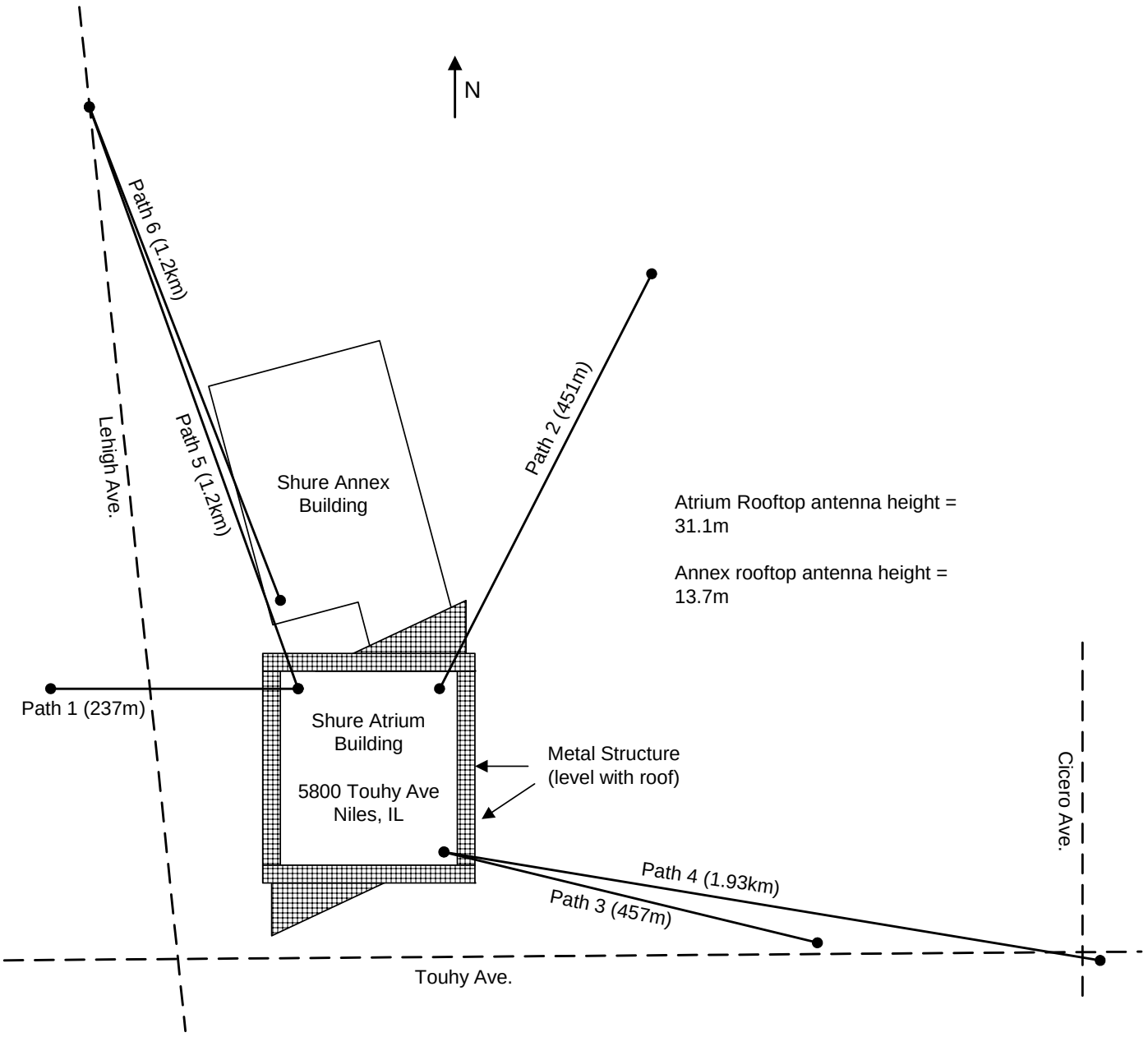


Shure Office Layout – 6th Floor (Indoor)

APPENDIX B: Spectrum Sensing Distance Study Diagrams and Photographs

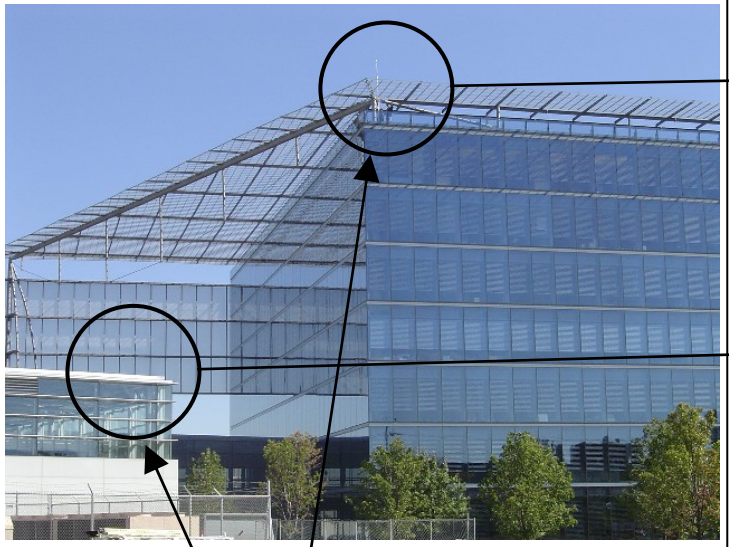


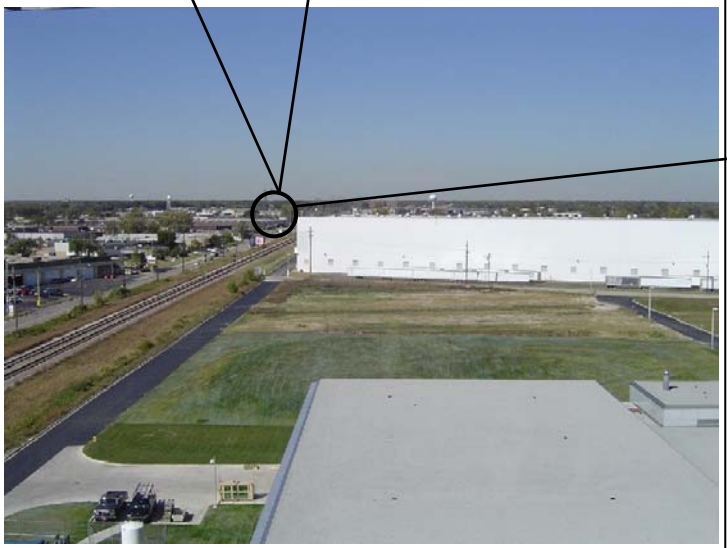
Spectrum Sensing Measurement Configuration
Shure Headquarters at 5800 W. Touhy Ave., Niles, IL



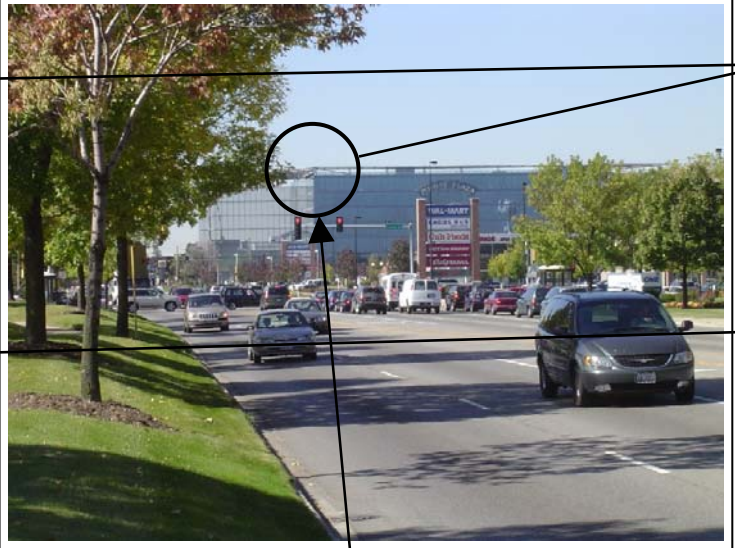
Shure Headquarters (Niles) Rooftop
Test Environment Diagram (Top View)

Field Measurements of Wireless Microphone Spectrum Sensing Distances





(Sensing range = 457 meters; Path 5)



(Sensing range = 1200 meters; Path 3)

Sensing omni-antenna (31 meters above ground)

Sensing omni-antenna (13 meters above ground)

Transmitting antenna (HH @ 1.5 meter above ground)

APPENDIX C: Spectrum Sensing (DFS) Model Parameters and Requirements

Shure is proposing that unlicensed devices operating in the TV bands use spectrum sensing (a.k.a. Dynamic Frequency Selection – DFS) to avoid co-channel interference to Part 74 devices including wireless microphones.

This proposed dynamic frequency selection model is based on that which was ordered in the recent 5 GHz proceeding[43]. The model has been extended with new variables and behaviors that are appropriate and required for protecting Part 74 devices.

DFS Parameter Values:

DFS Parameter for Wireless Microphones	Value
Channel Availability Check Time	30 sec
Non-Occupancy Period	60 minutes
Channel Detection Time	500 msec
Channel Setup Time	2 sec
Channel Opening Transmission Time (Aggregate transmission time)	100 msec
Channel Move Time (In-service monitoring)	2 sec
Channel Closing Transmission Time (Aggregate transmission time)	100 msec
Interference Detection Threshold	-107 dBm

DFS Parameter Definitions:

Channel Availability Check Time: the time during which a TV channel shall be checked for the presence of a wireless microphone signal with a level above the Interference Detection Threshold. No unlicensed device transmissions shall occur during this time.

Non-Occupancy Period: the required period in which, once a TV channel has been recognized containing a wireless microphone signal by an unlicensed device, the TV channel will not be selected as an available channel. No unlicensed device transmissions shall occur during this time.

[43] See FCC Report and Order re: "Revision of Parts 2 and 15 of the Commissions Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5GHz Band" (ET Docket No. 03-122) released November 18, 2003 at 22

Channel Detection Time: the maximum time taken by the unlicensed device to detect a wireless microphone signal above the Interference Detection Threshold within the current TV channel.

Channel Setup Time: the time taken by an unlicensed device to transmit control information to other unlicensed devices in order to establish an available TV channel.

Channel Opening Transmission Time: the aggregate duration of control transmissions by the unlicensed devices during the Channel Setup Time, which starts at the end of the Channel Availability Check Time. The aggregate duration of all transmissions shall not count quiet periods in between transmissions.

Channel Move Time: the time taken by an unlicensed device to cease all transmissions on the current TV channel upon detection of a wireless microphone above the Interference Detection Threshold.

Channel Closing Transmission Time: the aggregate duration of control transmissions by the unlicensed devices during the Channel Move Time, which starts upon detection of a wireless microphone above the Interference Detection Threshold. The aggregate duration of all transmissions shall not count quiet periods in between transmissions.

In-Service Monitoring: a mechanism to check a TV channel in use by an unlicensed device for the presence of a wireless microphone signal above the Interference Detection Threshold.

Interference Detection Threshold: is the level to be used by the DFS function to detect wireless microphone signals

General operational behavior of unlicensed devices implementing DFS for wireless microphones is outlined below.

Fixed/Access Devices

- All Fixed/Access devices operating in the TV bands shall use DFS to detect and avoid co-channel interference to wireless microphones for signals above the ***Interference Detection Threshold*****.**
- The Fixed/Access device initiates an unlicensed network by transmitting short control signals during the ***Channel Setup Time*** that will enable CPE and/or personal/portable devices to associate to the network. The aggregate transmissions during the ***Channel Setup Time*** shall be limited to the ***Channel Opening Transmission Time***.
- Before initiating a network on a channel, the Fixed/Access device shall perform a ***Channel Availability Check*** for the duration of the ***Channel Availability Check Time*** to ensure there are no wireless microphones operating on that channel.
- During normal operation, the Fixed/Access device must continuously monitor the operating channel ***(In-Service Monitoring)*** in order to detect wireless

microphone signals. The amount of time the Fixed/Access device can take to detect a wireless microphone signal above the detection threshold is the ***Channel Detection Time***.

- If the Fixed/Access device detects a wireless microphone signal, it stops transmissions on that channel and that channel is made unavailable for the ***Non-Occupancy Period***. The Fixed/Access device shall instruct associated CPE and/or personal/portable devices to stop transmitting on this channel, which they shall do within the ***Channel Move Time***. The aggregate transmissions during the ***Channel Move Time*** should be limited to the ***Channel Closing Transmission Time***.

CPE Devices

- All CPE devices operating in the TV bands shall use DFS to detect and avoid co-channel interference to wireless microphones for signals above the ***Interference Detection Threshold*.**
- An unlicensed CPE device must not transmit unless it receives a signal from a Fixed/Access device.
- A CPE device shall stop all transmissions whenever instructed by a Fixed/Access device. The CPE device shall not resume transmissions until it has again received a signal from a Fixed/Access device.
- During normal operation, a CPE device must continuously monitor the operating channel (***In-Service Monitoring***) in order to detect wireless microphone signals. The amount of time the CPE device can take to detect a wireless microphone signal above the detection threshold is the ***Channel Detection Time***.
- If the CPE device detects a wireless microphone signal, it informs the Fixed/Access device and stops transmissions on that channel and that channel is made unavailable for the ***Non-Occupancy Period***.

Personal/Portable Devices

- All personal/portable devices operating in the TV bands shall use DFS to detect and avoid co-channel interference to wireless microphones for signals above the ***Interference Detection Threshold*.**
- A personal/portable device initiates an unlicensed network by transmitting short control signals during the ***Channel Setup Time*** that will enable other personal/portable devices to associate to the network. The aggregate transmissions during the ***Channel Setup Time*** shall be limited to the ***Channel Opening Transmission Time***.
- Before initiating a network on a channel, a personal/portable device shall perform a ***Channel Availability Check*** for the duration of the ***Channel Availability Check Time*** to ensure there are no wireless microphones operating on that channel.
- During normal operation, a personal/portable device must continuously monitor the operating channel (***In-Service Monitoring***) in order to detect wireless microphone signals. The amount of time the personal/portable device can take to detect a wireless microphone signal above the detection threshold is the ***Channel Detection Time***.

- If the personal/portable device detects a wireless microphone signal, it stops transmissions on that channel and that channel is made unavailable for the ***Non-Occupancy Period***. The personal/portable device shall instruct associated personal/portable devices to stop transmitting on this channel, which they shall do within the ***Channel Move Time***. The aggregate transmissions during the ***Channel Move Time*** should be limited to the ***Channel Closing Transmission Time***.